

Ketchikan Bridge Project Summary Report

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KETCHIKAN BRIDGE PROJECT PORT OF KETCHIKAN, ALASKA TONGASS NARROWS

SUMMARY REPORT

OVERVIEW

This report describes an evaluation of various proposed bridge locations over a navigable waterway, and the safety and operational impacts that such a project may have on large passenger cruise vessels transiting the waterway to and from the Port of Ketchikan, in Southeastern Alaska. The study employed the full-mission shiphandling simulator at the RTM STAR Center in Dania Beach, Florida to simulate the water approaches to the port of Ketchikan with the addition of a highway bridge across the Tongass Narrows at three different locations. Participants in the study were comprised mainly of marine pilots from Southeast Alaska who routinely traverse the waters and have a vested interest in the future navigability of the Tongass Narrows passage to Ketchikan.

The Tongass Narrows is navigated by many vessels, the largest of which are among the newest classes of passenger vessels in the cruising industry. Ketchikan, is a port of call for these vessels. This study is intended to provide the data to support the continued safe navigation of passenger cruise ships and other large commercial vessels through the Tongass Narrows, after the construction of a connecting fixed bridge spans this waterway.

The simulator-based evaluation examined both North and South approaches to the port, because potential sites for the bridge would span the navigation channel either north of the passenger ship berth near the airport, or south of the berth, across Pennock Island.

Four ships were simulated and piloted in the Ketchikan database during this program. They represent typical large cruise ships that are expected to call at the port, and they characterize the various configurations of propulsion and steering controls unique to this class of vessels. The cruise ship models that were used represent some of the larger vessels of this type. These vessels were: “*Carnival Spirit*”, “*Carnival Destiny*”, “*Voyager of the Seas*” and “*Golden Princess*”.

DESCRIPTION OF TEST PROGRAM

Program Objectives

The purpose of this simulation-based study is to investigate and identify critical issues that could arise with the construction of a bridge across the Tongass Narrows and the

subsequent impact on the transit of large cruise ships through the Narrows. In order to provide a platform from which to experience the hydrodynamic and environmental effects on vessels transiting these bridge locations, on-line simulation is employed. This method of evaluation allows ship handlers to express opinions, comments, and support these opinions with empirical data provided by the simulator. Three potential bridge configurations/sites resulted in three database configurations for simulation testing:

- Option F1 – a high bridge over the East Channel (permitting large vessel transits) with a low bridge over the West Channel. Note: a low bridge over any of the navigation channels effectively limits use of that channel to smaller, usually non-commercial vessels (see figure 1).
- Option F3 – a high bridge over the West Channel with a low bridge over the East Channel (see figure 1).
- Option C4 – a high bridge over the North Channel in the vicinity of the airport. This location poses no navigational restrictions in either of the channels alongside Pennock Island (see figure 2).

In addition to the impact of the bridge on navigation in the Tongass Narrows, several secondary considerations are examined:

- Elicit comments regarding changes or additions to the aids to navigation that should be considered with each bridge configuration.
- Elicit comments and illustrate changes in procedures that might result from the removal of several hazards to navigation at the Port of Ketchikan consisting of:
 - Removal of 10 fathom shoal and 4 fathom rock at buoy “4A” near the passenger ship berth
 - Removal of the wreck and wreck buoy “WR6”
 - Removal of the 5 fathom rock northwest of Pennock Reef buoy ‘PR’

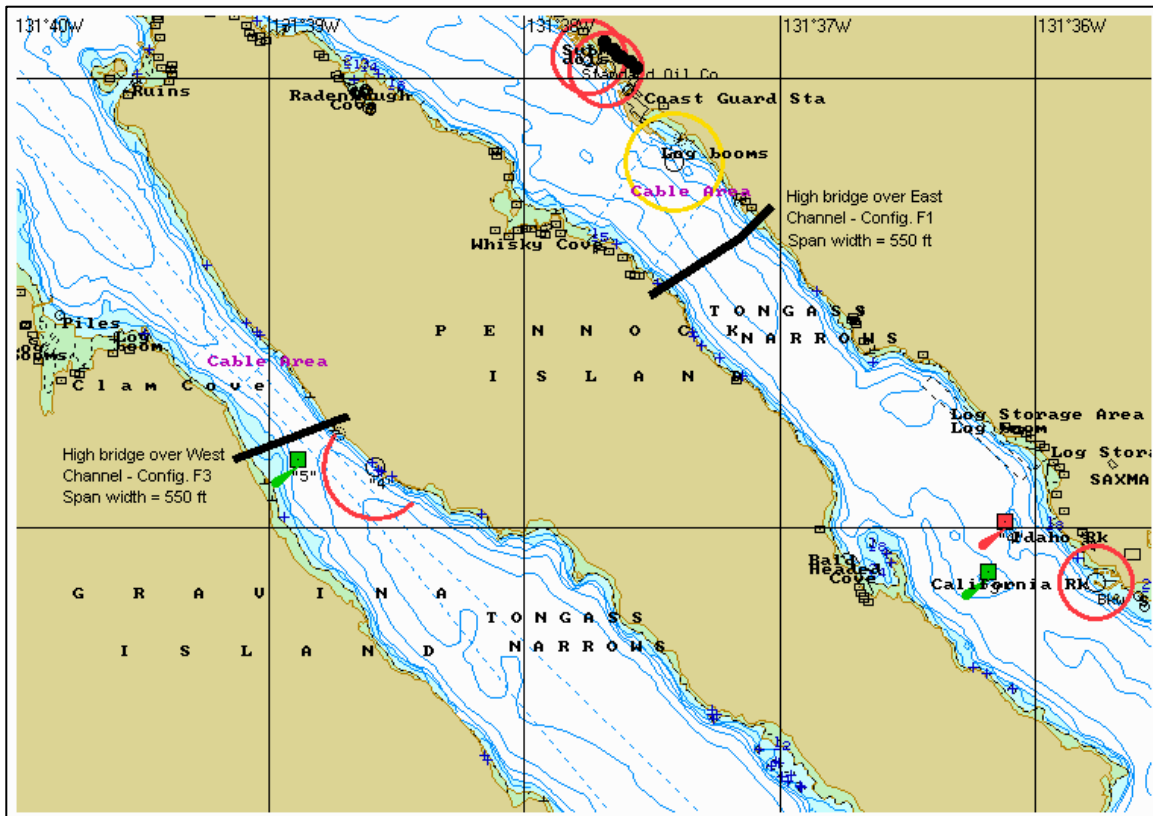


Figure 1 - Location of Proposed Bridge Sites F1 and F3 in East and West Channels

Participants

The ship handlers participating in this study were primarily active pilots from Southeast Alaska, representing the following organizations:

- **Southeast Alaska Pilots Association (SEAPA):**
 Capt. Jim Cathcart
 Capt. Robert Winter
 Capt. Karl Luck
- **Alaskan Coastwise Pilot Association (ACPA):**
 Capt. Erv Hagerup
 Capt. Jeff Baken
 Capt. John Baldry
 Capt. Doug MacPherson
 Capt. Glyn Seaberg
 Capt. Michael George

- **STAR Center:**

Capt. Victor Bericochea

All of the simulated transits were observed by a STAR Center Research Coordinator, who documented the run durations, noted observations of the actions of the participants, and who conducted debriefings following the exercises. STAR Center also provided an experienced helmsman to execute the steering orders and a simulator operator to configure the simulator, monitor proper operation of the simulator, record system data, and to generate track plots after each test run.

During the three weeks of simulation, a number of interested observers were present, representing the following organizations associated with this bridge project:

- **U.S. Coast Guard Aids to Navigation Branch:**
Cdr. Ed Sinclair
- **U.S. Coast Guard 17th District, Bridge Administration Program:**
James Helfinstine
- **The Glosten Associates:**
Dirk Kristensen
David Gray
- **MANTA Nautical Corp.:**
Trafford Taylor
- **Carnival Cruise Line:**
Capt. Leonardo Francolla
Capt. Domenico Tringale
- **Princess Cruises:**
Paul Morgan
- **HDR:**
- Mark Dalton

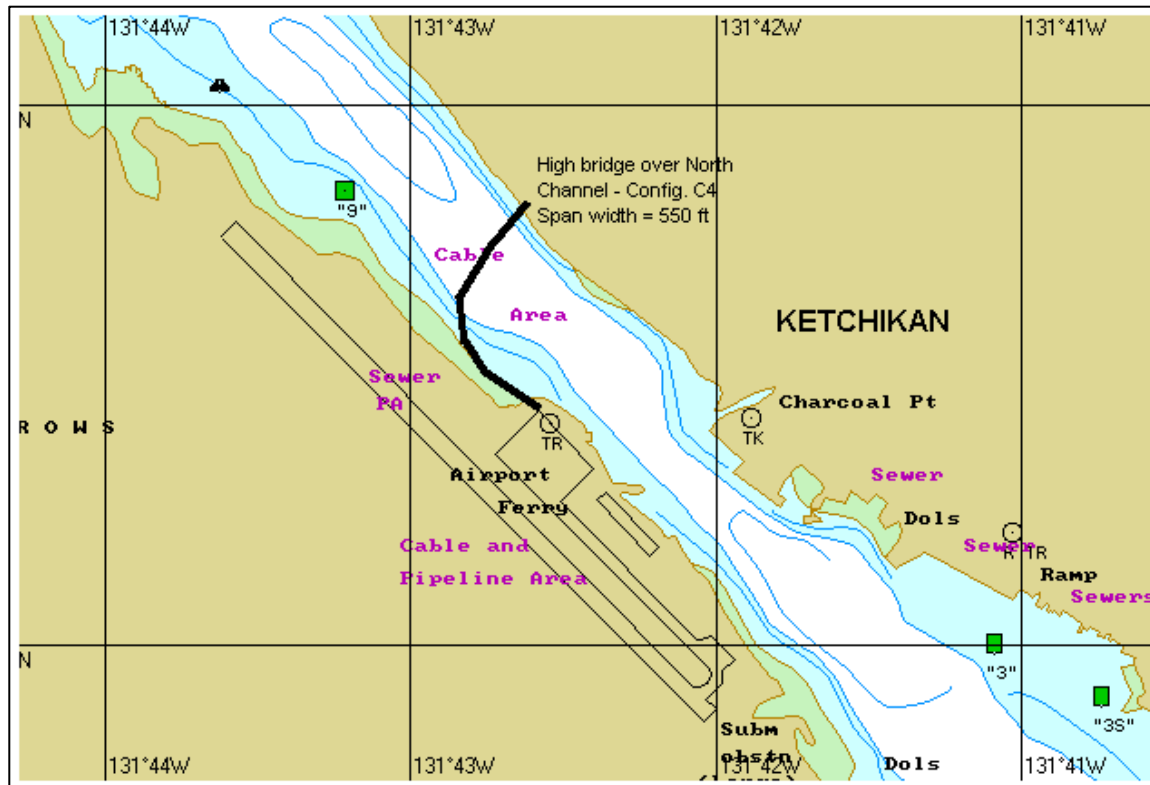


Figure 2 – Location of Proposed Bridge Site C4 at North Channel

Simulator Configuration

Simulation tests were conducted on STAR Center's 360-degree full mission bridge simulator. STAR Center's simulator bridge is a full size reproduction of a ship's wheelhouse. The equipment on the simulator bridge is representative of the hardware found on modern cruise vessels, including CRT conning displays, synthesized radar/ARPA displays, and sophisticated controls to operate thrusters and Azipod units.

Each ship handler conned (operated) the test vessel as the pilot would an actual ship, directing the movements of the ship by giving orders to the helmsman and requesting information from other members of the bridge crew when required. The simulator provided a 360-degree panoramic scene of the external environs as viewed from the wheelhouse. This provided a realistic environment for the participating ship handlers.

The only unique equipment provided was the simulator's "Birds Eye View" monitor, which was installed into the bridge console in lieu of an electronic chart display (ECDIS). This equipment was added because the charts available with the ECDIS do not reflect the bridge crossing configurations in Tongass Narrows that are the subject of this study. The "Birds Eye View" monitor is a component of the simulator equipment that presents an

outline of the vessel and the landmass, piers, and navigation aids of the navigable waterway in a manner similar to an electronic chart system display. It allowed the ship handlers to view an electronic display of the various bridge positions in a practical format familiar to the mariner.

Ship Response Models

Three ship response models were utilized for this study, which were the “*Carnival Destiny*”, the “*Voyager Of The Seas*” and the “*Golden Princess*”. A few initial runs were made with a fourth model, the “*Carnival Spirit*”. The “*Carnival Spirit*” was replaced early-on in the study in favor of the “*Voyager of the Seas*”, a much larger, and therefore demanding vessel. These ship response models are representative of the passenger cruise vessels that may frequent the waters of Tongass Narrows calling regularly at Ketchikan and other ports in Southeast Alaska. These models were also selected for the cross-section of maneuvering capabilities that they represent among modern cruise ships. These control systems include; conventional fixed propellers with rudders, both bow and stern thrusters, variable pitch propeller systems, and advanced Azimuthing propulsion systems. These vessels can be considered as maneuverable to highly maneuverable. They normally do not require tugs to assist with docking and undocking.

The three primary vessels that were simulated in this study are listed below and Table 1 provides the key particulars for each ship response model.

- “*Carnival Destiny*” –maneuverable, conventional propeller-rudder system
- “*Golden Princess*” –maneuverable, conventional propeller-rudder system
- “*Voyager of the Seas*” – highly maneuverable, Azipod propulsion system

The first six runs completed during the first session were conducted with the bridge opening constructed at an incorrect width, due to an error on the drawings from which the database was based: 750 feet instead of 550 feet. This initial error was corrected and the correct, narrower, width between the bridge supports (550 ft.) was used for all subsequent runs.

TABLE 1 – CRUISE SHIP MODEL SPECIFICATIONS			
Ship Name	Carnival Destiny	Voyager of the Seas	Golden Princess
Tonnage	101,353 GRT	137,276 GRT	108,000 GRT
LOA (m) / (ft)	272.0 / 892.2	311.0 / 1,020.1	289.5 / 949.6
Beam (m) / (ft)	35.5 / 116.4	38.6 / 126.6	36.0 / 118.1
Modeled Draft (m) / (ft)	8.2 / 26.9	8.6 / 28.2	8.05 / 26.4
Propulsion Type	Diesel Electric	Diesel Electric	Diesel Electric
Propeller Type / Number	Variable Pitch / 2 (inward turning)	Azipods / 2, Fixed Pod / 1	Fixed Pitch / 2 (outward turning)
Speed, Dead Slow (kn)	3.7	2.0	3.0
Speed, Maximum (kn)	22.6	23.0	24.5
Shaft HP (ea. shaft/pod)	22,797	19,713	28,161
Rudder Type / Number	Semi-Spade / 2	none	Semi- Balanced / 2
Max Rudder Angle	45 degrees	n/a	45 degrees
Bow Thruster (hp)	3 X 2,307	4 X 4,023	3 X 2,950
Stern Thruster (hp)	3 X 2,307	none (2 Azipods)	3 X 2,307

Conditions Tested

Test sessions were grouped by the proposed bridge site location. Daily session runs were conducted with one vessel model as the principle focus. The test conditions were varied for consecutive runs at each bridge site. For example, runs made with the ship response model, “*Carnival Destiny*” would be conducted at the bridge location in the North Channel (C4) near the airport. The conditions would then be altered at each successive run with varying wind, current and visibility for several Northbound runs. The wind, current and visibility conditions would then be varied while Southbound runs were conducted. When all the conditions were tested for the location with that vessel, the next set of runs would be conducted at a different bridge site. Different ship response models were used on each day of the session.

The worst-case scenarios for environmental conditions that were developed for this study include a “fair tide” (current running in the same direction as the ship is transiting), which would necessitate using more speed in order to maintain directional steering control. The wind direction was such that it blew from abaft the beam when the ship was navigating any of the three channel segments, either from dead astern or on the quarter. Wind velocity fluctuated about the base direction and speed parameters to simulate gusting.

The exception to this rule are several Southbound runs in the North Channel where the wind was on the bow (blowing from the Southeast direction).

The conditions evaluated during this study are presented in Table 2 below.

TABLE 2 – CONDITIONS EXAMINED DURING THIS STUDY					
Test Vessels (3)	Carnival Destiny		Voyager of the Seas		Golden Princess
Bridge Site Configurations (3)	East Channel “F1”		West Channel “F3”		North Channel “C4”
Run Direction (2)	Northbound			Southbound	
Current Conditions ¹ (2*)	Flood current, 1 knot			Ebb current, 1 knot	
Wind Direction (from) (4)	ESE (112.5°)		SE (135°)		WNW (292.5°) NW (315°)
Wind Speed (3)	15 knots		20 knots		30 knots
Visibility Conditions (3)	Full daylight, 10 nm visibility		Daylight with fog, 0.1 nm visibility		Full Night, clear visibility
* Test vessels always experienced a fair (following) current condition: Northbound runs with Flood current; Southbound runs with Ebb current.					
¹ During Week 1 session, current velocity conditions were 0.2 knots and 1.0 knots. After discussion with pilots, the following values were selected for use in subsequent runs/sessions: flood current in Nichols Passage is 3 knots while current in the Tongass Narrows (both ebb and flood) is 1 knot.					

There was no traffic introduced into the scenarios except for an occasional vessel in the anchorage when operating from the West Channel to the berth. This was the subject of many of the pilots’ comments: that normal traffic consisting of numerous small craft and fishing vessels routinely anchor in or near the channels. This would further hamper the ability to maintain our ship’s speed and to properly adjust the ship’s track in the channel when lining up for passage through the bridge. STAR Center staff elected not to utilize traffic in simulations because, it was felt, it would complicate results unnecessarily, due to the inherent unpredictability of that traffic, and make repeatability impossible.

All northbound simulated transits into the West and East channels started in Nichols Passage. Conversely, all southbound transits out of the West and East channels terminated in Nichols Passage. It is important to note that in reality the preferred and most common route into and out of these channels is via the Revillagigedo Channel.

TABLE 3 – NO. OF RUNS AT EACH PROPOSED BRIDGE LOCATION	
East Channel ‘F1’	52
West Channel ‘F3’	60
North Channel ‘C4’	36

Testing Procedure

Test runs were conducted at RTM STAR Center in Dania Beach, Florida over three sessions: April 29–May 3, May 13–17, and May 20–24 of 2002. The run matrix showing the conditions present in each of the simulator exercises are included in Appendix A. A total of 148 runs were accomplished during the three sessions. This total includes additional runs that were made outside of the run matrix. These additional runs were executed to examine, and compare the time required to transit and berth, using the East and West Channels, and/or to examine the effects on steering control on vessels during wind velocities of 35 and 40 knots.

During session one, wind speeds of 15 and 20 knots and current of 0.2 knots were simulated. The simulator provides for a random variability in wind speed and direction that can be set with different parameters. Initially, the wind varied in direction up to 30 degrees to either side of the stated direction and wind speed varied from 8-10 knots above and below the stated speed to simulate gusting winds. After a number of runs and consultation with the pilots, the variability in wind speed was reduced to 15 degrees either side of the stated wind direction and expanded velocity conditions of 15, 20 and 30 knots were incorporated into the run matrix for sessions two and three. The current was fixed at 1 knot for both the ebb and flood in the Tongass Narrows, and 3 knots in Nichols Passage.

On the first day of each weekly session, a briefing was provided to all the participants and observers as to the objectives and goals of the program. The first run was usually made with no wind as a familiarization transit for the participants to view the port database and to test the maneuvering response of the simulated vessel. Before each run commenced, each subject was briefed on the location and status of the vessel, the destination, wind, visibility, and tidal current conditions. Following each run, the ship handler, who acted as the pilot on that run, was provided with the “Run Evaluation Form” to complete. These are included in the Appendices B, C, and D of this report.

Data Collection Procedures

The simulator produces an abundance of data during each exercise run. This data includes the vessel’s trajectory, heading, speed, forces acting on the vessel, and extensive information relating to control settings. The trajectory information is used to generate track plots for each run.

Every ship handler filled out a “Run Evaluation Form” upon completion of his simulator test run. This form solicited opinions and comments regarding such information as adherence to the intended trackline, vessel controllability, overall safety of the maneuver, and task difficulty. Tabulation of the results from these forms contribute to the final evaluation of these exercises.

The participating ship handlers also summarized their expert opinions regarding the overall simulation program by completing a “Final Evaluation Form” after the weeklong

session ended. These are included in Appendix E of this report. The comments from these forms were analyzed, condensed, and are the basis for the conclusions and recommendations appearing in this report.

The STAR Center's staff maintained written observations regarding each simulator test run and noted any simulator-specific factors that might influence the interpretation of the results. All of the aforementioned factors were then considered in formulating the results and drawing the conclusions expressed in this report.

NAVIGATION ISSUES IN TONGASS NARROWS

General Navigation Issues and Existing Conditions

Comments from the pilots on the subject of large vessels transiting the West Channel in lieu of the East Channel provide the following information. The East Channel is presently the normal route used by cruise ships approaching Ketchikan from the south. The current flows along the axis of the channel in both ebb and flood conditions, so channel transits are familiar to the pilots, and present few new challenges, even with installation of a bridge, provided that the center span provides adequate width for large vessels.

Cruise ship transits, from the south, are characterized by a direct run from Revillagigedo Channel to Potter Rock with both adequate time and sea room to position the vessel for the East Channel entrance, at the south end of Pennock Island. From there, it is a relatively straight run up the channel to the passenger ship dock, where the vessel may be turned around to berth port side to in order to facilitate a quick and straightforward departure.

A review of the nautical chart for this passage, indicates that the most constricted area is inbetween California and Idaho rocks (approximately 482 feet apart). This is a well known navigational hazard which is clearly marked. During the simulations, this area did not present a problem, and the pilots were comfortable negotiating this area. One explanation for the ease with which vessels pass this obstacle (California-Idaho) is that the vessel is still carrying increased speed, aiding maneuverability at this point, and it has not yet slowed to channel transiting speeds (approximately 5 knots).

The pilots stated that large vessels almost never use the West Channel. In their opinion, the West channel is too narrow to be transited except in an emergency, for example, if the East Channel were closed or otherwise obstructed for some reason. The West Channel is narrowed (in the vicinity of the proposed bridge site), by a constriction due to the shoal area on the Gravina Island side. The flow of the current increases at this location due to this bottleneck, and it is reflected off the shoal, causing a "set" toward Pennock Island. In order to compensate for leeway (angle between ship's projected course and her track through the water) caused by the set of the current, or any wind affects on the vessel, the pilot would typically carry a "crab angle" that could be 5° or more from the trackline

course. The resulting increased swept path of the vessel would further reduce the available channel width, which is only about 3x the vessel's beam at its narrowest point.

Smaller vessels have no difficulty in the West Channel and routinely travel along this route.

Access to the West Channel via Nichols Passage will require a small radius turn at Gravina Point, where currents can run at 3 knots or more on the flood. During northbound transits, positioning of the vessel and maintaining adequate speed through the water will be critical at Gravina Point in order to make the turn into the West Channel and to align properly for passage through a bridge that might be erected there. The ability to be in the correct position when abeam of Gravina Point is further complicated by the necessity of avoiding the shoal areas in Nichols Passage. There are two possible strategies in avoiding the aforementioned shoal areas: one which takes the vessel inside the unmarked rock and close to Gravina Point; the other plan, positions the vessel outside this same rock but somewhat closer to the Walden Point reef. The former strategy will give the pilot very little margin for error in negotiating the turn on Gravina Point to the West Channel.

Although not simulated, a review of the nautical chart indicates that accessing the West Channel via Revillagigedo Channel would require 2 larger radius turns .

Departing the West Channel when southbound from Ketchikan will also require precise track keeping and good positioning to make the turn at Gravina Point and to avoid the shoals at the entrance to the Nichols Passage. Southbound transits from the East Channel provide the pilot with adequate time and room to stabilize the ship's track and speed from the point abeam of Potter Rock to Gravina Point, so as to be in good position entering Nichols Passage.

Minimum Channel Widths

The approximate narrowest width of each channel is shown below:

- Bridge Location 'F1', East Channel – narrowest part of channel is 495 feet between Idaho and California rocks, the remainder of the channel is 1150 feet wide.
- Bridge Location 'F3', West Channel – narrowest point is 555 feet wide.
- Bridge Location 'C4', North Channel – narrowest part of channel is 780 feet wide.

The bridge span at each location was 550', (approximately 4.36 X the beam of the widest vessel used in this study).

The transit of such large vessels (900' – 1000' in length) through these narrow channels requires precise track keeping, with little margin for error. Fortunately, these vessels have substantial main engine power and adequate power at the bow and stern to control lateral movements. It must be pointed out that the bow and stern thrusters, though powerful, only provide assistance at slow speeds (perhaps 4 knots and less through the

water). Under the conditions tested, the high wind profile of today's passenger cruise ships and the following current conditions of these test runs required higher speeds to be maintained by the ship handlers in order to maintain good directional control and reduced leeway corrections or 'crab angles'.

Restrictions on Handling Passenger Cruise Ships

Vessel speed restrictions exist in the Tongass Narrows, in order to reduce wake damage along the shoreline. A 7 knot maximum speed is in effect for vessels transiting both the East and West Channels from a point near where the proposed bridge sites are located on either side of Pennock Island, and extending north to Charcoal Point in the North Channel. This speed restriction is imposed on vessels traversing the Narrows from either direction.

Cruise ships are tender (having a small righting moment, easily tilted) due to their high wind profile/freeboard and relatively shallow draft. They are highly maneuverable and fast which can contribute to significant angles of heel (the inclination to one side by a vessel, in this case, caused by turning the vessel) when making good headway. For this reason, most modern passenger cruise vessels are equipped with stabilizers or other means of reducing or eliminating the rolling motion due to sea state, and heel angles due to high winds or turning of the ship. Use of stabilizers in these narrow channels would probably be considered impractical by vessel masters, therefore, turning a vessel sharply, or at speed must be considered before execution.

RESULTS AND CONCLUSIONS

During the study, there were no instances of vessels colliding with the bridge supports at any of the proposed bridge sites that were simulated. A grounding at Gravina Point did occur during session one, and was attributed to insufficient speed through the water for proper steering control, and inappropriate strategy for rounding the Point under extreme wind (Southeast 30 knots) and current (3.5 knots) conditions.

Heel angles (tendency to list, or lean) caused by wind, or in the case of most of our simulations, the result of changing the vessel's heading quickly, while traveling at speed, were noted during some runs. Heel, for any reason, is to be avoided if at all possible aboard cruise vessels, because it adversely affects passenger comfort. Excess heel (generally more than the accepted 5-7 degrees) was usually noted when vessels turned into, or from, Nichols Passage under extreme conditions of current and wind. Vessels are forced to turn more sharply when utilizing the West channel, due to navigational hazards near Gravina Point, than vessels entering or leaving the East channel, where turns were less restricted. It was not uncommon for angles of 12 to 14 degrees (*Voyager of the Seas*) when rounding the Point to access the West channel.

As a general comment, the speeds that were attained by the vessels were frequently higher than the speed limit allows (7 knots) when traversing the restricted speed zone of the port. The increase in speed, which often exceeded 10 knots over the ground, was observed to take place when the pilot was lining up for the passage through the bridge.

Due to the conditions applied to these runs, which included a fair current of at least 1 knot and following winds (or wind on the quarter) of from 15 to 30 knots with higher gusts, the higher speed was necessary to increase the controllability of the vessel under the adverse weather conditions while negotiating the bridge opening. Attempts were made to slow the vessel after passing the bridge, but speeds generally remained higher than the speed limit for some time afterward.

While the models used in this study do not simulate roll stabilizers, according to the participants, the stabilizers often would not be deployed in the restricted channels of the Tongass Narrows and it would require constant vigilance to keep the heel angle below 7° under the conditions that were simulated.

- The fact that no traffic in the Tongass Narrows was simulated obscures the fact that a slow moving vessel or tow running ahead of ownship, or an approaching vessel on the other side of the bridge, could result in having to maneuver more cautiously and slowly.

The inability to maintain the required speed through the water for directional control due to the presence of traffic (which may include small vessels anchored in or near the channel) will reduce the margin of safety in the bridge approach and bridge passage. The absence of traffic during the simulations was commented upon by the pilots, and is mentioned here to illustrate a complication for ship handlers, that would rely on pilot experience to overcome, and is not simulated.

East Channel Bridge Site

Little difficulty was evidenced with transits through the proposed bridge in the East Channel, and almost no comments were generated by the exercises at this bridge site. Two reasons suggest themselves:

1. This is the normal route taken by large vessels so that the ability to negotiate this channel safely is based on common practice and experience.
2. Although the bridge span width was the same as at the other proposed locations (550'), the opening was more nearly centered on a wider navigation channel making it easier to line up for the bridge approach.

Three track plots from the East Channel simulations indicated that the vessel transited close to Idaho rock, however, the pilots' did not appear to be overly concerned with this situation. Two of these runs were conducted with a 30-knot wind, which may have been a contributing factor. The third run was conducted by the RTM STAR Center provided pilot. It is believed that his lack of familiarity with this channel contributed to the limited clearance.

As is the case with the other bridge configurations, the bridge crossed the channel at a slight angle (approximately 16 degrees) so that the opening is not perpendicular to the normal trackline.

In comparison to the transits through the bridges at the other locations, the speed maintained when transiting the bridge opening in the East Channel was the lowest, at just above 8 knots over the ground, on average.

West Channel Bridge Site

The channel becomes very narrow at the location of the proposed bridge site due primarily to a shoal area on the western shore. For this reason, the pilots indicated that large cruise vessels do not traverse this channel as a rule, although it is suitable for smaller vessel traffic.

The proposed position of the bridge with support stanchions on the shoal area is characterized by the bridge span crossing the channel at an oblique angle (approximately 25 degrees). As a result, the bridge span in West Channel is not perpendicular to the centerline of the navigation channel and the center of the span is not aligned with the center of the channel. In the simulated southbound runs, the vessels were routinely maneuvered close to the shore of Pennock Island, which has a steeply inclined bank, in order to align properly for the bridge transit. The vessels passed through the bridge opening at a rather high speed for such restricted waters. This speed was necessary in order to maintain good directional control with the fair current, as well as to minimize any ‘crab angle’ that would be necessary to counter the effect of the moderate to high wind conditions that were simulated.

The constricted channel and relatively steep banks in this location may cause bank effects to be a consideration in this transit. Bank effects would be exaggerated by a combination of the required high transit speed and the close approach to the Pennock Island shore during the southbound passage to the bridge. The speed of the vessel when passing through the bridge opening averaged just under 10 knots when northbound and about 8.6 knots when southbound. The pilots commented that the bank effects that were experienced during simulation, were not as great as they would expect under the circumstances. If true, then the actual handling of the vessel in this bridge approach can be expected to present even more of a challenge than that observed in simulation.

The turn about Pennock Reef that would be necessary when the West Channel is used for transits to and from the passenger ship dock is approximately 120 degrees. In the simulations, this turn required the use of thrusters, required additional transit time, and exposed the vessel to environmental conditions in a confined anchorage area. Turning at Pennock Reef, whether North or Southbound, demands a tightly controlled maneuver involving minimum vessel speed to maximize thruster effectiveness. Northbound transits, in particular, required that shiphandlers reduce speed quickly after clearing the West channel, and prior to executing the turn in order that vessel heel angle is minimized. An average vessel speed of less than 3.8 knots produced minimal heel during simulations. Often during these maneuvers, turning from anchorage into the West Channel required the application of maximum thruster power during 20 knot wind conditions. It is possible that tug assistance could be requested for a vessel less maneuverable and with less thruster power than the “*Voyager of the Seas*” making a similar maneuver.

North Channel Bridge Site

The participants made comment on the fact that the location of the bridge opening is shifted to the southwest from the normal trackline in the channel. Traversing the bridge opening requires a ‘jog’ in the ship’s normal course in order to negotiate the span. Furthermore, the bridge at this site was not perpendicular to the vessel trackline (approximately 20 degrees). This has the effect of further reducing the usable span width.

The speeds maintained by the vessel through the bridge opening at this bridge site averaged just under 9 knots.

Removal of Navigation Obstructions

The removal of obstructions and Navigational aids (see Fig 3), is not necessarily directly related to proposed bridge locations, but is examined as a collateral issue. Several exercises were conducted to examine how the berth approach or departure would be affected by the removal of several known obstructions. The removal of the wreck and its buoy (“WR6”) may make it easier to maneuver through the anchorage enroute to or from the berth, particularly if another cruise ship is anchored there.

It is readily apparent to observers that the removal of the shoal and buoy “4A” located just off the passenger ship dock will significantly improve the safety of berthing operations at the dock, as well as of arrival and departure maneuvers near the dock. The track plots show different strategies were used to and from the berth in the absence of these hazards.

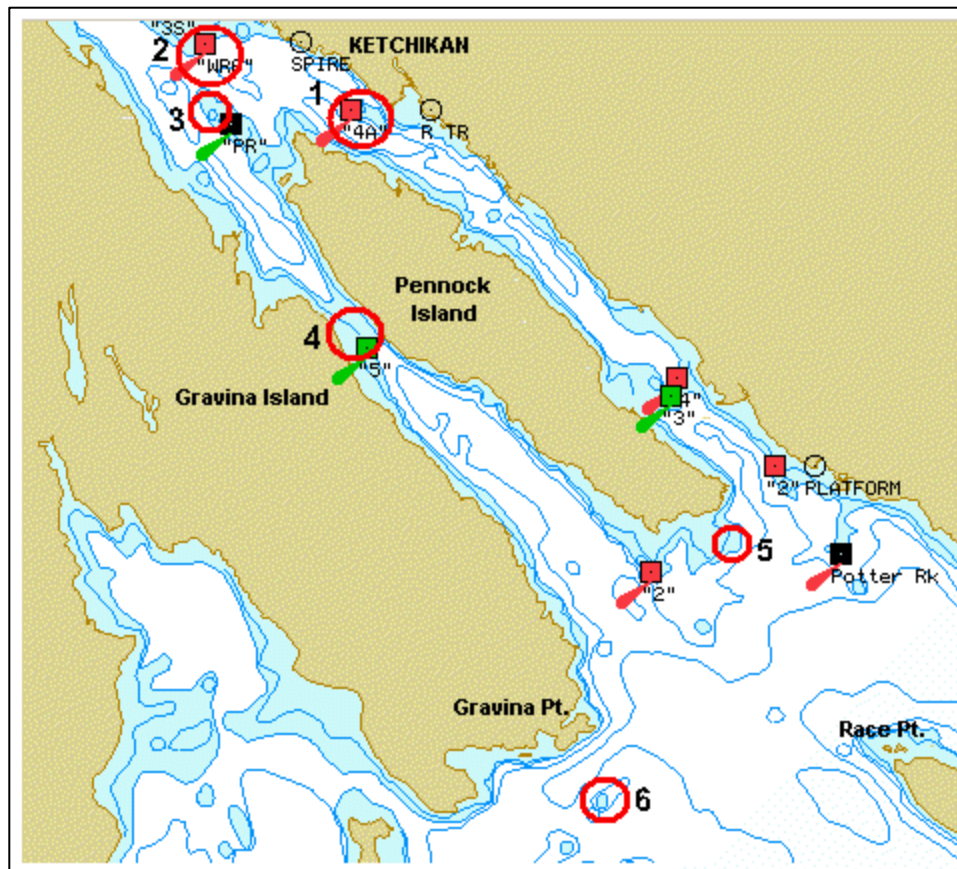


Figure 3 – Hazards Requiring Removal or Navigation Aids

Overall Transit Time to the Berth

Having safely negotiated the West Channel northbound, a cruise ship would then be required to turn about the north end of Pennock Island, avoiding Pennock Reef, and turning through about 120 degrees to proceed to the berth. Once the vessel is off the berth, the usual procedure is to turn the vessel so that it is headed outbound (North) for the departure. These additional low speed maneuvers increased the transit time to and from the berth over those transits that used the East Channel.

Nichols Passage

Nichols Passage at Gravina Point is characterized by strong currents and a shoal area to the south and has a known, but unmarked rock at a depth of 5 fathoms MLW that these ships routinely avoid. Two strategies are used when inbound to steer around this unmarked hazard: one is to pass close inshore when rounding Gravina Point, and the other is to transit the area outside the hazard by passing closer to the shoals west of Walden Point and steering for Race Point until Gravina Point is on the beam. Most outbound runs avoided the 5 fathom rock by staying close to Gravina Point. The turn at Gravina Point was difficult and stressful under the wind and current conditions that were

simulated, particularly when the vessel was entering or exiting the West Channel. Use of the West Channel required much more precise track keeping to negotiate the large turn and to position the vessel to avoid the obstructions in Nichols Passage.

SUMMARY OF POST-EXERCISE EVALUATIONS

The relative ratings by the participants following each exercise were based on a 5-point scale shown below. The evaluations from session two are summarized in Tables 4.1 through 4.3 for their assessment of run Safety, Level of Difficulty, and Stress, in order to get an indication of how the participants viewed the transits through the channel at each of the bridge locations. This summary is not statistically significant but merely shows a trend in the evaluations using the average of responses in each category.

OVERALL SAFETY				
ABSOLUTELY SAFE 5	4	3	2	NOT AT ALL SAFE 1
TASK DIFFICULTY				
EXTREMELY DIFFICULT 5	4	3	2	NOT AT ALL DIFFICULT 1
STRESS LEVEL				
EXTREMELY HIGH 5	4	3	2	NOT AT ALL STRESSFUL 1

Safety of the operation was rated somewhat lower by the pilots in the West Channel exercises compared with the East Channel and North Channel scenarios. While Safety was rated as ‘somewhat safe’ for both the North and East Channel configurations, the West Channel was rated as ‘somewhat unsafe’.

The Level of Difficulty and Overall Stress of the maneuvers show a correlation between one another. For the East and North Channel scenarios, the Difficulty and Stress evaluations are rated as ‘somewhat stressful’ and ‘somewhat difficult’ overall. Exercises conducted in the West Channel show higher stress and difficulty levels on average than the similar conditions in the other channels. This also correlates with the high number and the strength of the comments against the West Channel configuration.

TABLE 4.1 – OVERVIEW OF POST-EXERCISE EVALUATION FORMS			
East Channel (F1)			
Conditions	SAFETY	DIFFICULTY	STRESS
East Channel, Northbound Winds ≤ 20	4 +	3 –	3 –
East Channel, Northbound Winds = 30 kn	2 +	4 +	4 +
East Channel, Southbound Winds ≤ 20 kn	4 –	3 +	3 +
East Channel, Southbound Winds = 30 kn	4	3 +	3 +
East Channel, Reduced Visibility (Fog, Night)	4	3	3
East Channel by Ship Model			
East Channel, Northbound <i>CARNIVAL DESTINY</i>	4 –	3 –	3
East Channel, Northbound <i>VOYAGER OF THE SEAS</i>	3 +	4 –	4 –
East Channel, Northbound <i>GOLDEN PRINCESS</i>	4 –	3	3 –
East Channel, Southbound <i>CARNIVAL DESTINY</i>	4 –	4 –	4 –
East Channel, Southbound <i>VOYAGER OF THE SEAS</i>	4	3 –	3 –
East Channel, Southbound <i>GOLDEN PRINCESS</i>	4 –	3 +	3 +

TABLE 4.2 – OVERVIEW OF POST-EXERCISE EVALUATION FORMS			
West Channel (F3)			
Conditions	SAFETY	DIFFICULTY	STRESS
West Channel, Northbound Winds \leq 20	3 –	4	4
West Channel, Northbound Winds = 30 kn	2	4	4
West Channel, Southbound Winds \leq 20 kn	2	4 –	4 –
West Channel, Southbound Winds = 30 kn	2 +	4	4 –
West Channel, Reduced Visibility (Fog, Night)	3 –	5 –	5 –
West Channel by Ship Model			
West Channel, Northbound <i>CARNIVAL DESTINY</i>	2 +	4	4
West Channel, Northbound <i>VOYAGER OF THE SEAS</i>	2 +	4 +	4
West Channel, Northbound <i>GOLDEN PRINCESS</i>	1 +	5 –	5 –
West Channel, Southbound <i>CARNIVAL DESTINY</i>	2 –	4 –	4
West Channel, Southbound <i>VOYAGER OF THE SEAS</i>	3 –	4 +	4 –
West Channel, Southbound <i>GOLDEN PRINCESS</i>	2	5 –	4

TABLE 4.3 – OVERVIEW OF POST-EXERCISE EVALUATION FORMS			
North Channel (C4)			
Conditions	SAFETY	DIFFICULTY	STRESS
North Channel, Northbound Winds ≤ 20	3	3	3 –
North Channel, Northbound Winds = 30 kn	4 –	4 –	4
North Channel, Southbound Winds ≤ 20 kn	4 –	3	3
North Channel, Southbound Winds = 30 kn	3 –	4 –	3
North Channel, Reduced Visibility (Fog, Night)	n/a	n/a	n/a
North Channel by Ship Model			
North Channel, Northbound <i>CARNIVAL DESTINY</i>	3	3 +	4 –
North Channel, Northbound <i>VOYAGER OF THE SEAS</i>	4	3	3 –
North Channel, Northbound <i>GOLDEN PRINCESS</i>	3 +	4 –	4 –
North Channel, Southbound <i>CARNIVAL DESTINY</i>	4 –	3	3
North Channel, Southbound <i>VOYAGER OF THE SEAS</i>	3 –	3 +	3
North Channel, Southbound <i>GOLDEN PRINCESS</i>	4	3	3 +

OBSERVATIONS AND RECOMMENDATIONS

The construction of a bridge across Pennock Island will effectively close one of the channels (East or West) to large cruise ship traffic, wherever the low bridge is located. If the location of the low bridge is across the East Channel this will contribute to transit delays for large vessels accessing the cruise terminals from the south.

Were a ship casualty to occur in the narrow East or West Channels (whichever had the high bridge span), then all approaches from the south would be closed for large vessels, and would require substantial voyage deviations to circumnavigate Gravina Island in order to use the northern approach channel. The following comments, specific to each proposed bridge location, are derived from the final evaluations and verbal comments provided by the participants in this study.

West Channel Recommendations

1. According to the pilots, the West Channel is considered unsafe for transits by any large cruise ships without a bridge (present condition). They believe that this route should only be considered for the low bridge option or (better) no bridge at all. They offered the following reasons:
 - Current set due to the shoal area on the Gravina Island side (at the proposed bridge location) is toward Pennock Island at the constriction. The narrow channel provides insufficient width to carry much of a ‘crab angle’ to counter this set. This is also true when wind is on the quarter or on the bow, causing leeway which must be corrected by carrying a substantial ‘crab angle’. The pilots believe that a limit of 20 knots of wind may be the operational limit for large cruise ships in this channel, due to narrowing of the waterway at the bridge site.
 - The pilots stated that they could not safely take a large vessel through this channel due to its narrow constriction and the current set toward Pennock Island in the vicinity of the shoal area near the proposed bridge site. Only one ship’s width is available to either side at the narrowest point of the channel. There would be no margin for error at the bridge: e.g., a gust of wind, engineering casualty, error in responding to helm commands, opposing traffic, etc., would allow very little time to react and correct.
 - Additionally, the use of the West Channel as the only navigation route from the south would likely preclude the use of the anchorage north of Pennock Island. Entering cruise ships would have to make the approximately 120° turn around Pennock Island and then turn again nearly 180° to berth Starboard side to the pier. Turning through the anchorage with other large vessels present would increase the risk of operations.
 - Significant turns are required about Pennock Island Reef and at Gravina Point to get into and out of the West Channel. When performed with moderate to high winds and up to 3 knots of current, safety is reduced. On a southbound run from the berth, the substantially large turn about the north end of Pennock Island is difficult, with the ebb current and high wind tending to set the vessel down on the Gravina Island shore to the west. This is complicated by the necessity of maneuvering around anchored vessels and avoiding an unmarked 5-fathom rock northwest of the Pennock Reef buoy. As a result, it is difficult to line up properly for the bridge when coming out of this turn.
 - On southbound runs it was necessary to stay close to the Pennock Island side when approaching the bridge, where the bank effects must be considered and controlled. The higher speeds that were required to maintain steering control through the bridge opening with the wind and current conditions that were simulated would significantly increase the bank effects with the vessel so near to the shore.

- West Channel transits, even were the bridge absent, are expected to significantly increase the transit times to and from the passenger ship berth. The large turns around the north end of Pennock Island and then turning around at the berth, which can only be accomplished while stopped or at slow speed, could add delays of as much as 45 to 60 minutes for the arriving vessel. In order to make this channel safer for navigation of large vessels, such as the cruise ships simulated in this study, the shoal on the Gravina Island side should be removed. This will both eliminate, to some extent, the constriction and possibly reduce the current set toward the Pennock Island shore. Other modifications to make this a more suitable route would include:
- Although not tested, the pilots' recommended that the bridge span should be increased another 100 to 150 feet.
- Construct the bridge so that the navigable span is perpendicular to the channel trackline, and the span itself should be centered about the navigable channel. The oblique angle of the bridge with the channel that was simulated has the effect of reducing further the narrow opening. This caused the pilot to alter course quickly just before the bridge to steer the vessel straight through the span, followed by a second alteration upon leaving the bridge opening to rejoin the normal trackline.
- Remove/relocate the cables crossing the channel near the bridge site, which prevent the use of the anchors in an emergency.
- If the West Channel were to become the main northbound approach from the south (site of the high bridge span) then the area south of the passenger ship dock in the East Channel should be kept clear for use as a turning basin during the cruising season. Prohibit anchoring of packer vessels in this area.

East Channel Recommendations

Should a bridge be constructed in the East Channel, it is recommended that the cables presently located near this site, be raised from the bottom and run along the bridge, or otherwise relocated. This would facilitate the use of anchors in an emergency without risk to the cables. Other recommendations include:

- Although not tested, the pilots' recommended that the bridge span should be increased another 100 to 150 feet.
- Construct the bridge so that the navigable span is perpendicular to the channel trackline, and the span itself should be centered about the navigable channel.
- Since the narrowest section of the East Channel is between California and Idaho Rocks, consideration should be given to the removal of one (Idaho) or both of these hazards to navigation.

North Channel Recommendations

1. Although not tested, the pilots' recommended that the bridge span should be increased another 100 to 150 feet.
2. Construct the bridge so that the navigable span is perpendicular to the channel trackline, and the span itself should be centered about the navigable channel.

Changes or Additions to Navigation Aids and Obstacle Removal

It was recommended that range lights be added at the bridge location for transits in both directions. For example, if the West Channel becomes the site for the high span, range structures could be erected at "East Clump", south of the airport, for northbound transits through the bridge.

Other recommendations that were supported include (see Figure 3):

- (1) Remove the shoal off the passenger ship berth and its buoy "4A".
- (2) Remove the wreck and wreck buoy "WR6".
- (3) Remove the 5-fathom hump northwest of the Pennock Reef buoy "PR" or mark it with an appropriate aid to navigation.
- (4) Remove the shoal area on the Gravina Island side of the West Channel, if West Channel becomes the main navigational channel with construction of the high bridge at the proposed location.
- (5) Add a buoy to mark the extent of the shoal area at the south end of Pennock Island across from Potter Rock.
- (6) Remove the 5-fathom rock near Gravina Point in Nichols Passage or mark it with an appropriate aid to navigation.

SUMMARY OVERVIEW

The port of Ketchikan can, at this time, be accessed from the North, and via two different channels (East and West), from the South. The installation of a fixed bridge across any of the three approach channels will impact ship navigation in these channels to some degree. Narrowing of a navigable waterway, especially at a time when cruise vessels size seems ever increasing, should be considered carefully. Installation of a low bridge in any channel would effectively close that waterway to any large vessels, and limit access to two approach channels, limiting arrival and departure options. Previous sections of this report outline shortcomings and complications that were experienced at each location, if any. Apprehensions and concerns of participating pilots were, for the most part borne out by simulation. Since all three bridge locations contribute to, or complicate channel navigation, an overview of the location options is summarized briefly here.

All bridge designs should provide for maximum horizontal clearance at the center span. The 550' clearance used in simulation was adequate, however, a widening of 100-150'

would greatly increase the margin of safety. Bridge supports should be perpendicular to the navigation channel whenever possible. Approaches to the bridges should provide adequate maneuver room for vessels to correct the angle of attack/approach just prior to bridge transit, and should not, if possible, be hampered by the narrowness of the channel, where bank effects etc., could complicate that approach.

Realizing that many factors will influence bridge design and location not considered here, bridge locations ranked by navigation concerns only, are presented here.

C4 Northern bridge. *Impact:* Minimal navigational problems. *Advantage:* Familiar channel for ship handlers. Does not affect or further limit the 3 channel approaches to the area.

F1 East Channel high bridge. *Impact:* Design closes West channel to vessels with an air draft of over 60 feet (limiting large vessel options to two usable channels). *Advantage:* Familiar channel for ship handlers, , quick access to cruise pier, proven route.

F2 West Channel high bridge. *Impact:* Design closes East channel to vessels with an air draft of over 60 feet (limiting large vessel options to two usable channels). Narrow channel, with no plans to widen channel. More difficult to enter and exit at the south end. More difficult to access cruise pier. *Advantage:* None

These conclusions were reached based on a narrow view, by considering navigation issues only. It is not our intention to make light of the design work of bridge planners, and we realize that many considerations were incorporated into the current proposals.